ABSTRACT

Dynamic stability derivatives play an important role in the design of control systems for aerospace vehicles These parameters can be approximately estimated by various computational methods For optimal design of control systems, these approximate values are generally inadequate The approximation arises due to the difficulty in modeling the complex flow phenomenon Hence, it would be necessary to obtain a set of stability parameters for design using experiments in a wind tunnel These derivatives can be refined further by conducting actual flight trials on the prototype vehicles

Experiments in wind tunnel generally use forced or free oscillation methods for the measurement of aerodynamic stability derivatives of the model Usually, these forced or free oscillation rigs are capable of imparting one degree of freedom oscillations to the model Imparting multiple degrees of freedom oscillation depends on the versatility of the rig In general these setups involve complex mechanisms and that are model specific To overcome these deficiencies model semi free and free flight techniques are developed In these methods the model is allowed to fly in a limited number of degrees of freedom in a wind stream and stability derivatives of the model are extracted by applying the system identification techniques on the recorded motion time history data

Preliminary experiments conducted in single degree of freedom on an aircraft model having servo driven elevator to estimate the pitch damping derivative have earlier shown that the dynamic flight technique to be capable of accurately determining some of the derivatives Successful experiments of this kind have been reported in literature

The present work is an extension of the single degree of freedom technique In this work we develop an experimental method to estimate aerodynamic stability derivatives of a flight vehicle configuration by conducting wind tunnel experiments on a model which is allowed to oscillate in two degrees of freedom

A novel suspension system based on "bifilar suspension technique" which has two degrees of freedom is designed for exciting lateral oscillations of a flight vehicle model in wind tunnel A simple finned configuration (designated as the Basic Finner) is chosen for this study A mathematical model is developed for the motion of the model which is constrained by the suspension setup to execute small amplitude oscillations in two(lateral and yaw) degrees of freedom in a wind stream The model suspension system consists of two vertical rods hinged at their upper ends to a fixed support and pivoted at the lower end to the model The setup is instrumented so as to measure the displacement of suspension

rods in the lateral plane at the supports by potentiometers One of the fins is servo driven and instrumented for measuring its angular movement

Three configurations of the suspensions are chosen for the present study Wind tunnel experiments on the basic finner model can be divided into (1) wind-on steady state experiments and (2) wind-off / wind-on dynamic experiments In wind-on steady state experiments the model is mounted on a six component strain gauge balance in the wind tunnel and aerodynamic forces acting on the model at some wind speed are measured

In dynamic experiments, first the model is initially disturbed manually under wind-off conditions in the wind tunnel Motion time history of the model is recorded Since there are no aerodynamic forces acting on the model, from this experiment only the model inertia parameters such as moment of inertia and frequencies of oscillation are estimated by applying the system identification techniques on the recorded time trace of free oscillations data

Wind-on dynamic studies consist of (1) free oscillation (2) forced oscillation experiments In wind-on free oscillation experiments, the model is given an initial disturbance manually and motion time histories are recorded In wind-on excited oscillation experiments model is excited to oscillate by giving various control inputs namely, multistep (3-2-1-1), doublet (2-2), impulse etc , to the servo driven fin thro' a radio control system Response of the model for various control is recorded Stability derivatives of the model are estimated by applying system identification techniques to the recorded data

As there is a possibility of instability of motion in this setup, stability of the model motion has been analyzed using eigenvalue analysis Measured and predicted model speeds are compared Results from dynamic experiments are copmared with results from wind-on steady state experiments and available data in literature and found to be in reasonably good agreement